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**Department of Environment
Water Resources Division**

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Mineral Development Division**



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**Environment Canada
Inland Waters Directorate
Dartmouth, Nova Scotia**

**SURFICIAL GEOLOGY OF THE WATERFORD RIVER BASIN
St. John's, Newfoundland**

by

Martin J. Batterson

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**Urban Hydrology of the
Waterford River Basin
Technical Report #1**

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Abstract

The Waterford River basin is situated in the path of the rapid urban expansion of Mount Pearl and St. John's, Newfoundland. The consequent modification of the drainage pattern and the water geochemistry has offered an opportunity to undertake a detailed examination of the effects of urban development on drainage basin hydrology. The study of the surficial geology is but one aspect of the Waterford River Basin Urban Hydrology Study.

The overburden in the Waterford River basin is generally thin (0-5 m), and is composed of a very compact, poorly sorted lodgement till with high (10%) silt-clay content overlain by a till deposit that is looser, coarser and more permeable in nature, derived by supraglacial or melt-out processes. Water movement is largely determined by the overburden mantle, so the surficial geology is an important component of any hydrological study.

Hydrologically, the most significant features of the surficial mantle are its thinness and the influence of bedrock upon drainage, and the slow percolation and discharge of water through the compacted lodgement till unit. Urban development affects discharge by reducing lag times for entry of water into the drainage system which, consequently, increases the potential for flooding and erosion, as well as altering water geochemistry. These effects will become progressively emphasized unless preventative measures are implemented.

INTRODUCTION

The characteristic responses of fluvial systems to urban development are well known (e.g. Gregory, 1977). The removal of the natural vegetation, with the soil's consequent lagged response to precipitation events, and its replacement by an urban fabric with its far more rapid response, affects not only channel geometry and discharge, but also water geochemistry.

Unfortunately, results from studies in Europe and elsewhere in North America cannot be applied readily to Newfoundland, with its unique position both in terms of its climatic regime and geomorphology. It was partly in recognition of this problem that the Waterford River Basin Urban Hydrology Study was started as a joint venture between the Canada and Newfoundland Departments of Environment. Although more than 60% of the basin area remains under a natural cover, this is being diminished by the continued expansion

of the city of St. John's and the town of Mount Pearl. Detailed analyses of discharge, water geochemistry and groundwater levels is an ongoing process under this study. For further details concerning the hydrological aspects of the project, the reader should refer to the Waterford River Basin Urban Hydrology Study Plan (Environmental Management and Control Division, Department of Environment, St. John's, Newfoundland).

This project is designed to provide a more complete picture of the surficial geology of the Waterford River basin. It is considering surface features and their distribution as well as the depth, degree of consolidation, and texture(s) of the overburden mantle, each of which affects water movement.

This report reviews background information on the physical setting, geology, soils and glacial history of the area; relates the methodology used in the field work and its

rationale; and presents and discusses the results. Appendices include field and supplementary data. Maps of terrain units, overburden thickness and texture are also included.

THE WATERFORD RIVER BASIN: PAST AND PRESENT CHARACTERISTICS

Physical Setting

The Waterford River basin covers an area of 61 km², and is situated immediately to the west-southwest of St. John's Harbour (Figure 1). The main Waterford River stretches 13 km from Bremigens Pond in the west to St. John's Harbour in the east, but field investigations ended at the Waterford Bridge Road bridge. This represents a field area of 51 km².

The major tributary of the Waterford River is South Brook, which extends 11 km from headwaters where flow is intermittent to the confluence with the main stream at Bowring Park.

Significant relief features in the Waterford River basin are confined to the basin perimeter (Figure 2). Kenmount Hill in the north is the highest peak (261 m above sea level), but its outline is generally smooth due to glacial action. In contrast, the South Side Hills display a more rugged outline, the result of a combination of lithology and the paucity of glacial deposits. Turtle Hill (206 m above sea level) is the highest feature there.

The lack of significant relief has resulted in generally very gentle (<2%) to gentle (2-5%) slopes across the area. Steeper slopes of about 10-30% occur only around Kenmount Hill, the South Side Hills and the hills north and south of the headwaters of South Brook.

Geology

The geology of the St. John's Peninsula has been the focus of many studies, e.g. Brueckner (1969a, 1979), Hsu (1976), Hughes and Brueckner (1971), McDivitt (1969), Papezik (1974), and Rose (1952).

The following is a compilation of the most pertinent facts, especially where they relate to the field area (Figure 2).

The St. John's Peninsula is part of Brueckner's "Eastern Block", located between the Topsail Fault Zone in the west and the Atlantic Ocean in the east. Lithologies in this area consist of a west to east progression of granitic and volcanic rocks to a line running from Topsail in the north to County Pond in the south. East of this line, sedimentary sandstones and shales predominate.

The volcanic rocks of the Harbour Main group are the oldest rocks on the St. John's Peninsula. They consist primarily of basaltic rocks but rhyolite occurs in places. These rocks are intruded by younger granite, quartz monzonite, and diorite of the Holyrood pluton ("Middle Block" rocks). Both these groups interfinger laterally with, and are unconformably overlain by, a sequence of marine sediments consisting of greyish-green siltstone, greywacke and tuffaceous beds known as the Conception Group.

The Conception Group rocks grade upward into those of the St. John's Group, which consists of the Middle Cove Formation below and the Outer Cove Formation above. The St. John's Group rocks are overlain by those of the Signal Hill Group, which comprise the Gibbet Hill Formation and the Battery Formation (Figure 2). The

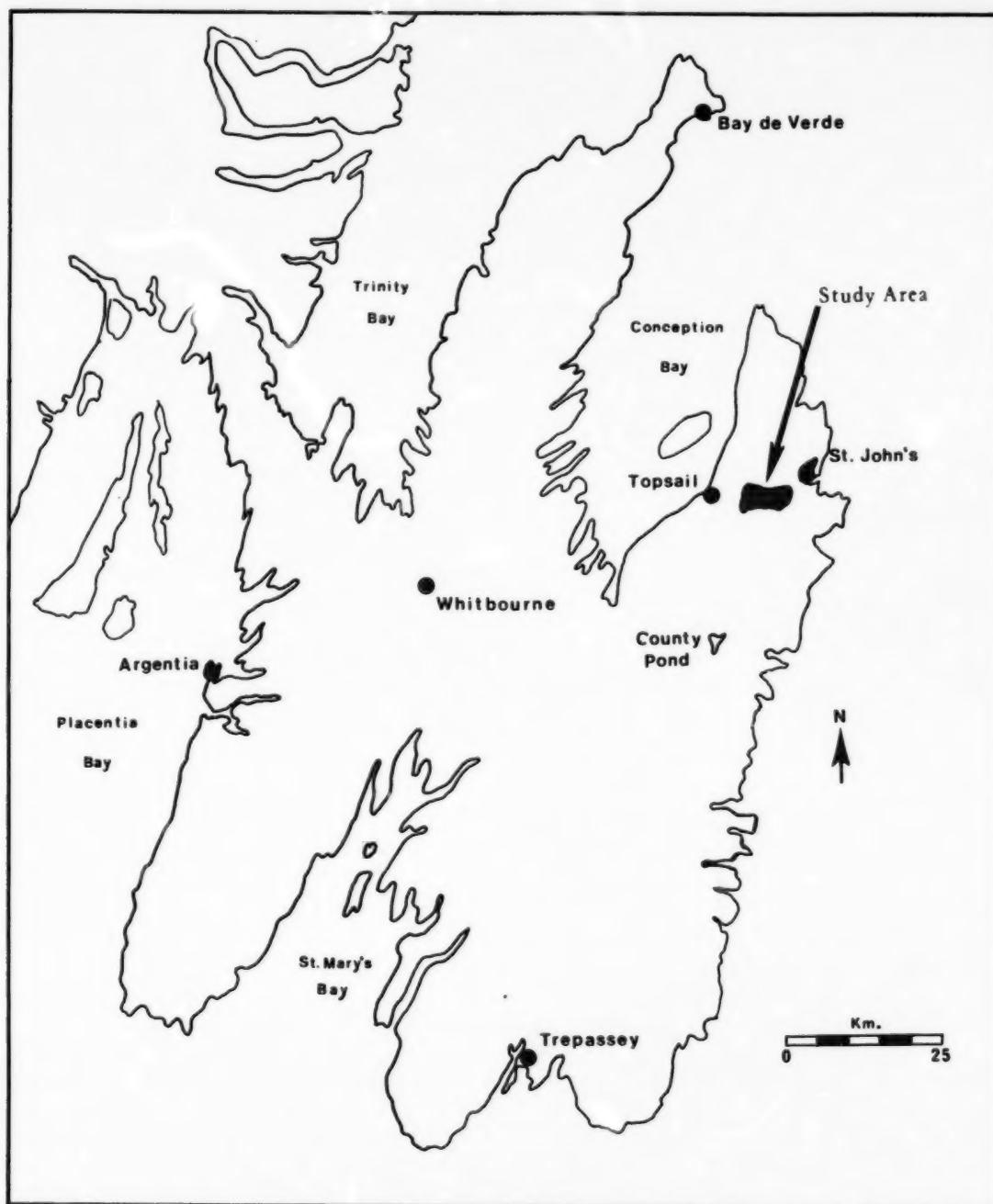
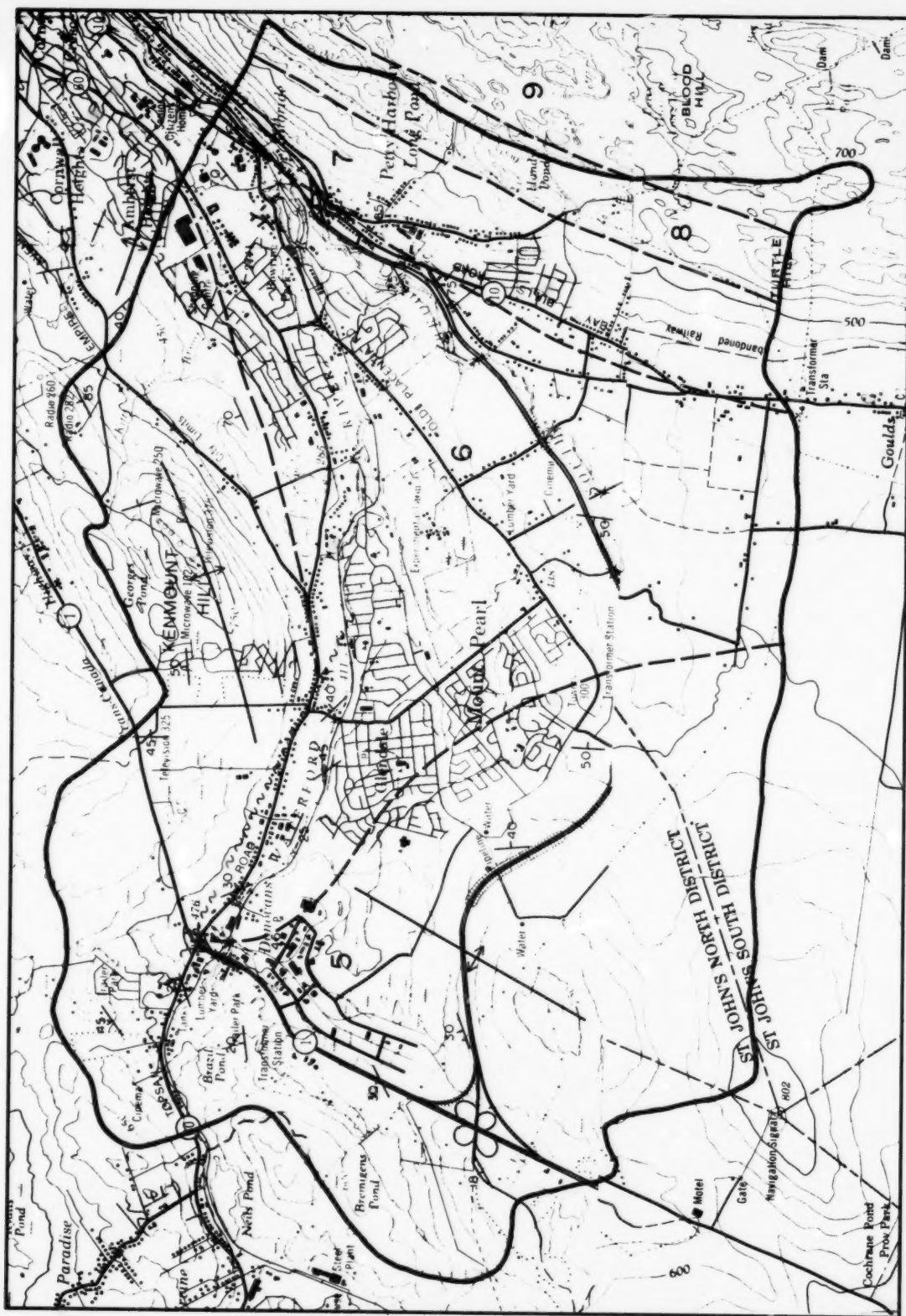


Figure 1: Location of field area.

Figure 2: Geology of the Waterford River basin.



LEGEND

PRECAMBRIAN

SIGNAL HILL GROUP

- 9 Battery Formation: Red sandstone and shale.
- 8 Gibbet Hill Formation: Green-grey sandstone and shale.

ST. JOHN'S GROUP

- 7 Outer Cove Formation: Interbedded grey to black sandstone, siltstone and shale.
- 6 Middle Cove Formation: Black shales.

CONCEPTION GROUP

- 5 Green-grey, red, thin to medium bedded greywacke, siltstone, shale and chert with minor airfall crystal tuff and tuff.

SYMBOLS

Bedding.....	
Geological boundary (approximate).....	
Fault (assumed).....	
Anticlinal axis.....	

Geology from Hsu (1976)

boundaries between these formations and groups are gradational.

The St. John's Formation consists mainly of dark grey to black shale which becomes sandier and softer upward through the formation until rocks of the Signal Hill Formation dominate. Similarly, these grey to greenish-grey sandstones and conglomerates grade into the red and greenish-grey sandstones of the Black Head Formation. This boundary is

defined where pebble beds grade into sandstone.

Within the basin, rocks of the St. John's Group dominate in the eastern and central areas, and rocks of the Conception Group outcrop in the west and north. Harbour Main Group rocks are not exposed in the field area. Rocks of the Signal Hill Group are confined to the higher elevations of the South Side Hills. Although tills of local origin are

expected within the basin, exotic rock types along the supposed line of glacial transport may also include volcanics of the Harbour Main Group, located in outcrop a minimum distance away of approximately 4 km.

Soils and Vegetation

Two major soil orders (podzols and gleysolics) occur within the basin. These are subdivided into four soil units named according to their representative type section (Heringa, 1981).

At least 75% of the basin is covered by soils of the podzolic order (Figure 3). These are well to imperfectly drained soils that developed under coniferous and mixed forest vegetation (especially balsam fir, black spruce and birch) and heath in cold to temperate climatic regimes. These acidic soils exhibit a distinct profile: a surface organic horizon (L-H), with possibly an associated Ah horizon below; a leached (Ae) horizon; and an illuviated B horizon containing varying degrees of organic matter, iron and aluminum. It is on the basis of these variations that the podzolic soils are subdivided in this area.

A more visually noticeable differentiation of podzolic soils within the basin can be derived largely on the basis of drainage, a composite reflection of topography and stoniness of the soil. Cochrane soils occur in undulating to hilly terrain (5-20% slopes) and are well to moderately well drained. Surface stoniness ranges from moderately stony (class 3 on a scale of 0 (nonstony) to 5 (excessively stony)) to excessively stony (class 5). Cochrane soils comprise approximately 50% of the field area.

Pouch Cove soils also occur on undulating terrain (2-10% slopes),

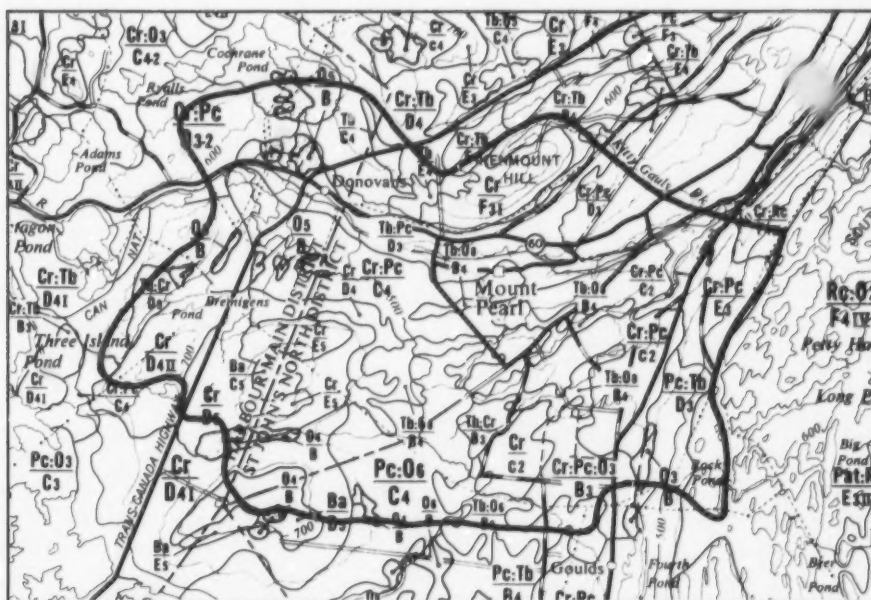
but they are imperfectly drained and are consequently classed as a Gleyed Humo-Ferric Podzol. These soils are exceedingly stony (class 4) on lower slopes, but less stony on hilltops and upper slopes. This is presumably a reflection of gravity sorting. Pouch Cove soils are restricted to the central southern part of the field area.

Of minor significance within the basin are Bauline soils and organic soils. Bauline soils are characterized as thin, very well drained, excessively stony soils which develop on moderate to steep slopes (15-40%) and are interspersed between rock outcrops. Bauline soils are confined to the exposed peaks north and south of the headwaters of South Brook. Organic soils are widely dispersed across the basin and, as with the Bauline soils, comprise far less than 10% of the total.

The remaining 25% is composed of soils of the Gleysolic order. These soils, which are saturated and under reducing conditions, support hydrophytic vegetation, e.g. tamarack, black spruce and heath plants. Within the basin, Torbay soils represent the Gleysolic order. They are generally confined to the valley bottoms of the Waterford and South Brook rivers and to the lower, poorly drained areas south of Ruby Line.

Soils within the basin are generally thin (<60 cm), and are underlain by a shallow parent material. This has been described (Heringa, 1981) as an olive to olive grey, amorphous, very gravelly, very firm when dry, and very strongly acidic (pH 4.9) till.

Agricultural and forestry capability in the area is low. The restrictions are adverse topography and the stoniness and shallowness of the soil.



TOPOGRAPHIC CLASSES SIMPLE AND COMPLEX TOPOGRAPHY

Single slopes	Multiple slopes	Slope %
A.....depressional to level	a.....nearly level	0 to 0.5
B.....very gently sloping	b.....gently undulating	0.5+ to 2
C.....gently sloping	c.....undulating	2+ to 5
D.....moderately sloping	d.....gently rolling	5+ to 9
E.....strongly sloping	e.....moderately rolling	9+ to 15
F.....steeply sloping	f.....strongly rolling	15+ to 30
G.....very steeply sloping	g.....hilly	30+ to 60
H.....extremely sloping	h.....very hilly	over 60

ROCKINESS

- I — 2 to 10 per cent exposed bedrock; some interference with tillage but not enough to make intertilled crops impracticable.
- II — 10 to 25 per cent exposed bedrock; tillage restricted to hay crops or improved pasture.
- III — 25 to 50 per cent exposed bedrock; sufficient rock outcrop to make all use of machinery impracticable, except for light machinery where other soil characteristics are especially favorable for improved pasture.
- IV — 50 to 90 per cent exposed bedrock; sufficient rock outcrop to make all use of machinery impracticable.
- V — over 90 per cent exposed bedrock.

STONINESS

- 0 — Non-stony.
- 1 — Slightly stony; slight to no hindrance to cultivation.
- 2 — Moderately stony; some interference with cultivation.
- 3 — Very stony; sufficient stones to constitute a serious handicap to cultivation.
- 4 — Exceedingly stony; sufficient stones to prevent cultivation until considerable clearing is done.
- 5 — Excessively stony; too stony to permit any cultivation (boulder or stone pavement).

CONVENTION

Soil Symbol:	Soil Series	Example
Topography Stoniness Rockiness		Nh:07 d41

A single soil series symbol indicates that the series occupies 80% of the area or more. Complex symbols denote that the first named series occupies 40 to 80% of the area, and the second and third together occupy 20-40% of the area. Soils occupying less than 20% of an area are not designated.

*For organic soils, the symbol **06F5**, for example, is interpreted as follows:

- 0 is the basic symbol, denoting Oligotrophic Peat
- 6 is the von Post decomposition class on a scale of 1 (least decomposed) to 10 (most decomposed) estimated on the material at 50 cm depth.
- F indicates presence of Flushets (ponds)
- 5 indicates depth of organic material, where measured in feet.

SOIL SYMBOL	SOIL SERIES
Tb	Torbay
Cr	Cochrane
Pc	Pouch Cove
Ba	Bauline

Figure 3: Soils of the Waterford River basin (after Heringa, 1981).

A major component of the surficial mantle is urban development, which accounted for 24% of the basin in 1976. It is estimated that this had increased to 35% by 1982 as a result of rapid urban expansion, particularly in Mount Pearl. This percentage is expected to continue to increase.

Quaternary History

The glacial history of the Waterford River basin cannot be viewed in isolation. An overview of Avalon Peninsula glaciation is here examined, and the field area fitted into the general chronology.

The most extensive and interpretively significant works on the Quaternary history of the Avalon Peninsula are those of Summers (1949) and Henderson (1972), the latter's report based on fieldwork in the 1940's and 1950's. Recent investigations are few and have concentrated on small areas, with the aim of clarifying established chronologies, e.g. Rogerson and Tucker (1972), Vanderveer (1975), Eyles and Slatt (1977) and Mellars (1981). Tucker (1976) provides a summary of the most pertinent works on both the Avalon and the main part of the island.

It is generally believed that pre-Wisconsinan deposits do not exist on the Avalon Peninsula (MacClintock and Twenhofel, 1940, Summers, 1949, Henderson, 1972). MacClintock and Twenhofel (1940) contended that, during the Wisconsin stage, the Avalon was covered by ice from the main part of the island, but this theory is not supported by evidence. In contrast, Summers (1949) and Henderson (1972) believed that the Avalon maintained its own ice cap at that time, citing radial striae, lack of pebble lithologies from outside the Avalon, and distribution of landforms as evidence. Also, there is disagreement as to the extent of ice

on the Avalon Peninsula. Grant (1976, 1977), working on the Burin Peninsula, extrapolated his work to the Avalon and, based on meltwater channel distribution and aerial photograph interpretation, considered that ice on the St. John's Peninsula only reached as far north as Pouch Cove. Henderson (1972) however, considers that ice extended beyond the present coastline.

The presented sequence of glacial events on the Avalon is derived from Henderson (1972), with modifications by Rogerson and Tucker (1972) and Summers (1949). During the maximum Wisconsin, the main ice dome was centered over St. Mary's Bay. Initial southerly flow was blocked by eastward moving ice in the Cabot Strait. Ice then built up in St. Mary's Bay and was forced onto other areas of the Avalon, particularly north through Trinity and Conception Bays and southeast toward the Grand Banks. At that time, either ice advanced 150 km or more onto the Grand Banks (Alam and Piper, 1977; Slatt, 1977), or the Grand Banks maintained its own ice cap (Rogerson, 1982). Ice over the St. John's Peninsula was thin and possibly local, but confluent with the main ice cap.

Ice initially retreated about 13,000 years ago (Tucker, 1976). Following wastage of Cabot Strait ice, flow down St. Mary's Bay increased and diminished to the north and east. Accumulation centers shifted to higher elevations. A series of minor ice caps developed, some of which may have been present throughout the entire late-Wisconsinan (Summers, 1949); one such center was northwest of St. John's.

Recent evidence presented by Macpherson (1982) suggests that glaciation, on the eastern Avalon peninsula at least, was by a downwasting process. Ice left the Hawke Hills some time before 10,000 years

ago, while ^{14}C dates of basal organic sediment from lower elevations are more recent, e.g. 9270 ± 150 years old (GSC-2601) from Sugarloaf Pond northeast of St. John's. After final deglaciation, the landscape was further modified by an extensive and intensive period of periglacial activity. However, the most conspicuous feature of the post-glacial period is bog-growth (Brueckner, 1969b).

Only the northern part of the St. John's Peninsula retains evidence of the main ice flow (Vanderveer, 1975); the remainder was influenced by thin, local ice which radiated east and west from the spine of the peninsula. Ice direction was topographically controlled rather than imposed by pressure gradients within the main ice mass. Summers (1949) considers that the main effects of glaciation in this area were the deposition of till and the modification of drainage, rather than any significant erosional activity. The till smoothed the surface relief by filling the depressions. Till thicknesses are, therefore, variable, ranging from 0 to 6 m (Henderson, 1972). Postglacial drainage consists of small streams which meander across the depositional surface in search of major valleys which were only partially filled, in contrast to the preglacial drainage system, which was probably bedrock-controlled.

METHODOLOGY

Introduction

This project extended from June to September, 1982. The goal was to provide a detailed analysis of the surficial geology of the Waterford River basin by considering glacial deposits and their thickness, and landform types and their distribution, as a complement to the overall Waterford River Basin Study.

Initial Research

Initial research provided an insight into the variability of terrain types and generated background data to aid the field program. Coloured aerial photographs (1:12,500 scale; NF 78005, 84-105; NF 78056, 50-62; NF 78005, 13-21 and 37-46) were used to determine terrain types in the field area, using a surficial landform classification developed by the Department of Mines and Energy.

Data were also generated by investigating consultants' reports of land developments within the study area. These ranged from reports on individual buildings, e.g. the provincial Agriculture building on Brookfield Road, to major housing developments, e.g. Newtown, Mount Pearl. Data included terrain descriptions, overburden thicknesses and types, grain size analyses, and bedrock information.

The results of supplementary information concerning the geology, soils and Quaternary history, were also collected during this stage, and were presented earlier.

Field Research

Field research was designed to confirm, modify and supplement initial data. In total, 195 point descriptions were completed across the field area. This represents an average data collection point spacing of 500 m across the basin. Urban development concentrations restricted field observations, but information was gathered wherever possible (e.g. house foundations, water/sewer line construction). An adequate road system, both paved and off-road, facilitated research and a sample point was placed, where possible, within each of the terrain units designated by the aerial photograph interpret-

ation. Of the 195 points, 60 were profile descriptions, 56 were bedrock descriptions and 79 were general descriptions of gravel pits, accuracy of the aerial photograph interpretation, overburden thickness, and local areal observations.

Whenever possible, existing sections were selected for examination, e.g. roadcuts and construction sites. Elsewhere, sections were from shallow hand-dug pits. Profile analysis entailed measuring each stratigraphic unit and describing the colour, texture, sorting, clast roundness and lithology, structure and drainage of each. Samples were taken of selected units to provide an even distribution across the field area. A total of 68 samples were taken, of which 19 were sieved through a nest of four field sieves (-60/63 mm, -50/32 mm, -40/16mm, and -30/8 mm). The others were grab samples of the finer than 8 mm fraction. Pebble samples were also collected.

Due to the lack of sections to bedrock across much of the basin interior, especially across Kilbride-Goulds, overburden thickness data were generated using a Huntco FS-3 portable hammer seismograph. Seven sites were selected to provide a complete areal network. However, because the observed bedrock topography is so variable, the validity of overburden thickness data so determined, is unknown. The thicknesses measured represent the seven specific points and may not accurately reflect the surrounding thicknesses.

Other data collected were glacial striae and landform orientations.

Laboratory Analyses and Data Compilation

This stage, designed to quantify the data, helped to validate con-

clusions of the field work, and to provide a basis for further interpretation.

Grain-size analyses involved wet sieving through a 40 (63 micron) sieve and subsequent dry sieving of the coarser than 40 (63 micron) fraction using standard procedures outlined by Bowles (1978). The finer than 40 fraction was analyzed by the pipette method. Results were plotted using a small Hewlett-Packard computer and a program devised by Slatt and Press (1976).

Pebble analyses were conducted on the -40 retained fraction. Pebbles were described on the basis of silt-clay coating, weathering and staining, as well as by rock type, sphericity, roundness, fracture faces, colour and grain size.

RESULTS AND DISCUSSION

Terrain Analysis

A detailed aerial photograph analysis of terrain features completed before the field work was field checked and then modified during a review of the aerial photograph data. On this basis, a terrain map was produced (Map A, in pocket). Although detailed, the map reveals an essentially 'simple' progression of terrain styles, which, for ease of interpretation and discussion, may be subdivided into five units (Figure 4).

Areas of bedrock concealed by a thin (0-2 m) veneer of overburden or vegetation (Rc) comprise approximately 15% of the field area. Generally, these areas are confined to the uplands, particularly in the south-western, northern and eastern parts of the basin. The bedrock is often lineated, and provides good geological exposures. Other minor areas of Rc are noted along the margins of South Brook and the Waterford River in their lower reaches, and in numer-

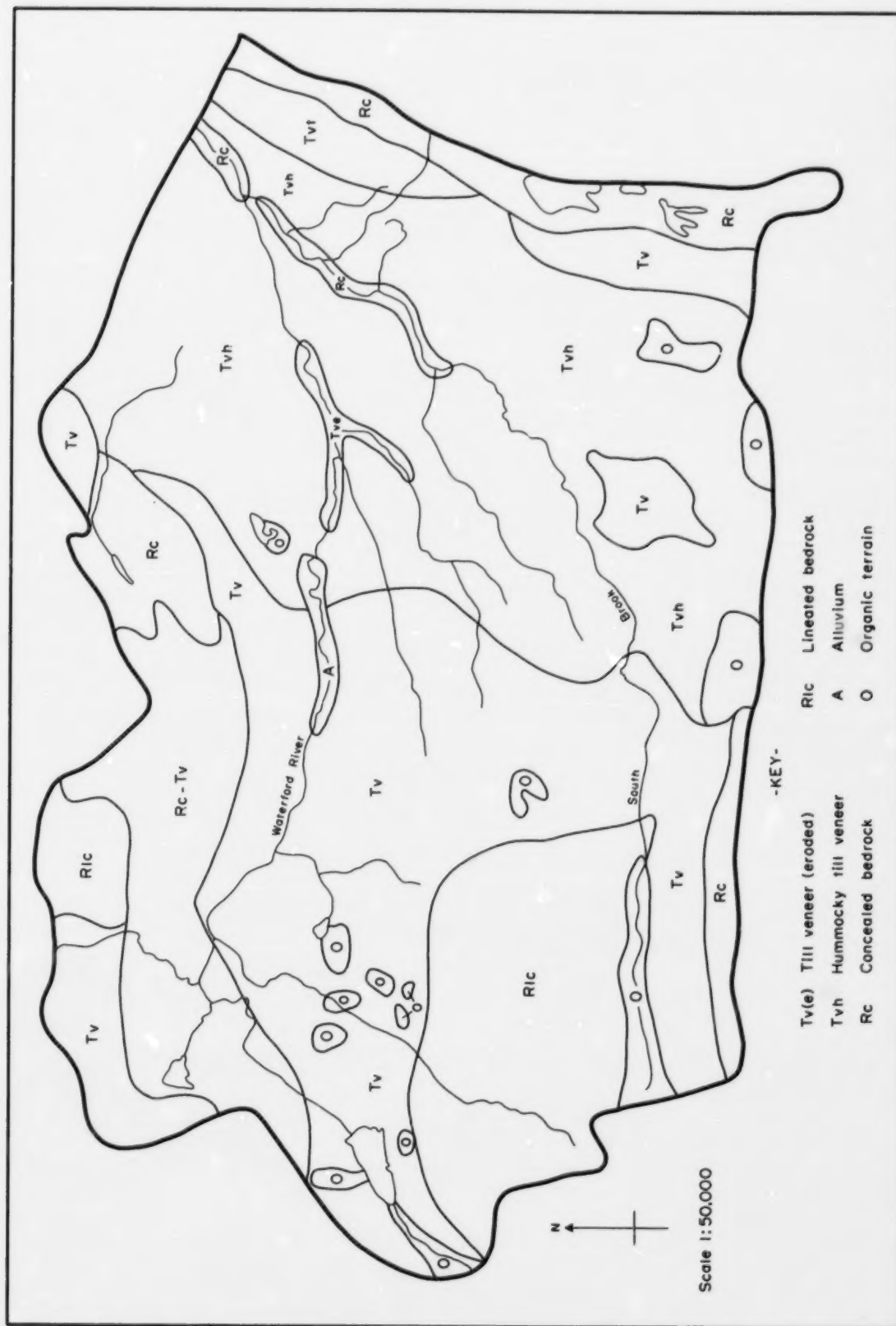


Figure 4: Summary of terrain units within the Waterford River basin. (See Map A in pocket for details).

ous isolated spots across the basin. These latter areas were not included in Figure 4, but are considered by the notation //Rc after the major terrain types on Map A.

About 60% of the field area is covered by a veneer (average 3 m) of till (Tv). This till covers the gently sloping areas in the western half of the basin between areas of Rc to the north and south. There is some variability within this terrain unit, notably in a dissected till veneer along incised sections of South Brook and Waterford River, in gullied sections of the uplands at the headwaters of South Brook, and in a terraced till veneer along the South Side Hills east of Petty Harbour road. A similar, but single, terrace is also present around Kenmount Hill and near the Clearview Drive-In in Paradise.

Toward the eastern half of the basin, the Tv unit merges into Tvh, a hummocky till veneer. The major difference between the two units is the presence of an irregular till surface on the latter which in some places has indistinct lineations. The poor development of these lineations, however, excludes a drumlinoid characterization, and the term 'hummocky' is preferred. Till thicknesses are similar to those in the Tv unit. The Tvh unit pinches out toward the east, where bedrock control becomes dominant again, and to the northeast, where constriction of the valley is evident.

The remaining 5-10% of the basin is largely composed of organic terrain. This occurs along the low areas at the headwaters of South Brook and Waterford River, at isolated localities along their courses, and in depressions over the entire basin. The material underlying the organic terrain varies. Sections east of Donovans Industrial Park are underlain by till; other areas are

underlain by bedrock. The depth of the organic terrain is also variable, ranging from less than one metre to reported thicknesses of over four metres in the Goulds area. These areas presumably represent pre-existing ponds which have been infilled by plant succession.

A small area (about 2%) of the basin is covered by recent alluvial deposits. The largest area occurs immediately north of Mount Pearl along the Waterford River. Upstream, patchy alluvium occurs along the river banks, but a well defined flood plain has not developed. Downstream, incision of the valley has occurred which restricts the development of alluvial deposits. A small area of alluvium is located at the entrance to Bremigens Pond; this may be a glaciofluvial deposit related to the deglaciation of the last ice sheet.

An effort was made to determine the terrain unit boundaries in the urban areas. However, the large degree of urban development in the central and eastern parts of the basin, in particular, made this very difficult and some unit variations may have been overlooked.

The Overburden Mantle - Thickness

The overburden topography of the Avalon Peninsula is extremely variable, as it fills the numerous shallow bedrock depressions in this terrain (Figure 5). Observations throughout the Waterford River basin are consistent with this, as a 1.5 to 2.0 m change in overburden thickness over 10 m or less is not uncommon. The steep dip of the bedrock (approx. 70°) may account for this variability (Figure 6).

Despite the variability, an overburden thickness map has been prepared (Map B [in pocket] and Figure 7). The map is generalized and ignores the many small bedrock out-

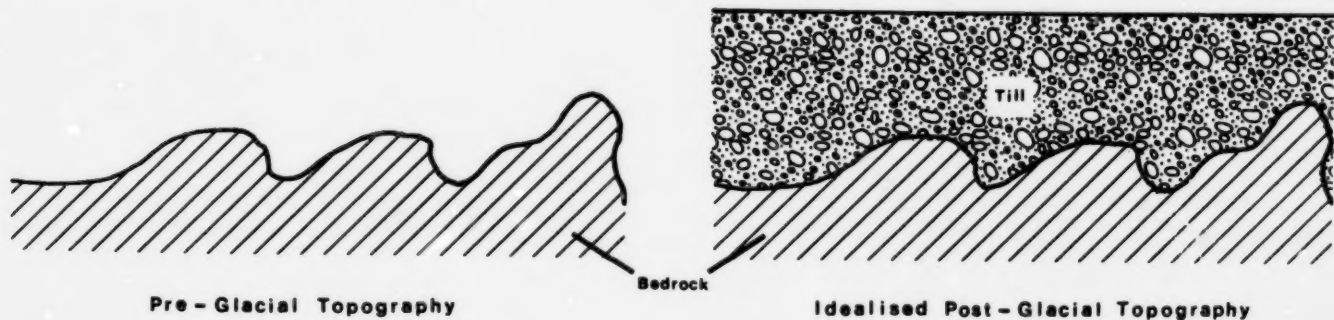


Figure 5: Effect of glacial deposition of topography.

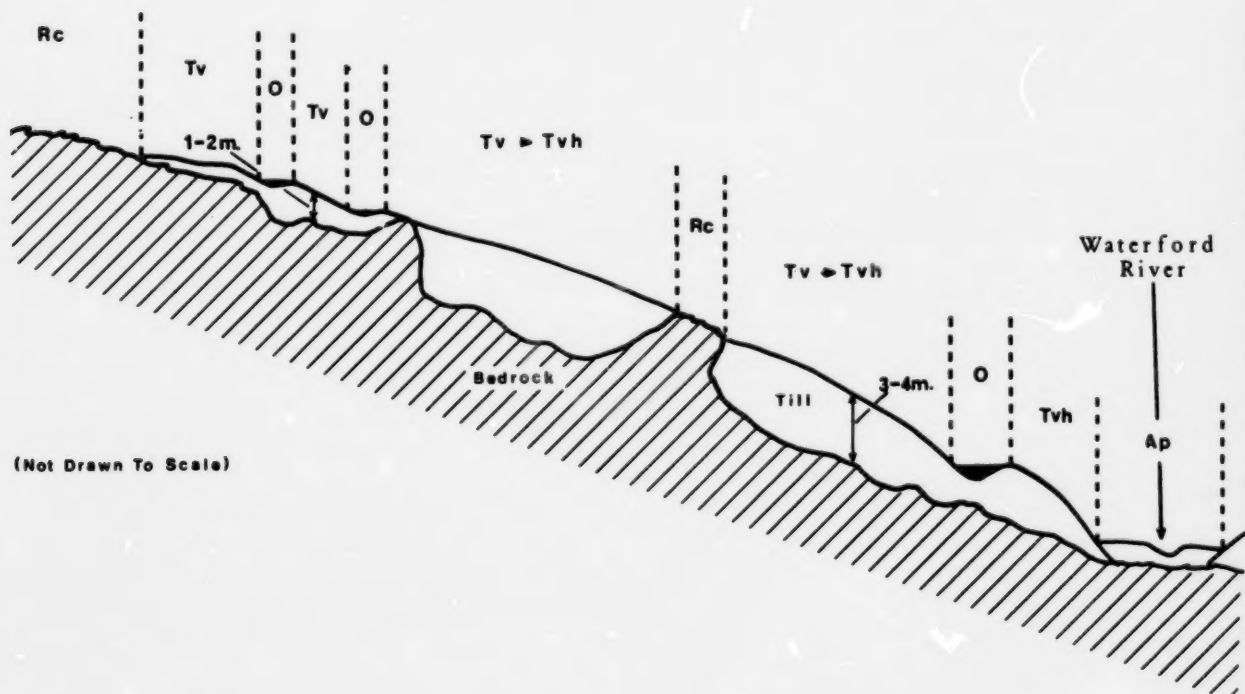


Figure 6: Sketch illustrating the variability of the overburden thickness.

Despite the variability, an overburden thickness map has been prepared (Map B [in pocket] and Figure 7). The map is generalized and ignores the many small bedrock outcrops which protrude across the basin. It illustrates trends rather than provides specific onsite values, the accuracy of which may be ± 1 m. Several main points are illustrated by the map as follows:

- 1) Areas of no overburden are confined either to hilltops, e.g. Kenmount Hill, the area around the Modern Paving Quarry to the west of the Harbour Arterial - Trans Canada Highway intersection, the hilltops north and south of the headwaters of South Brook, and the South Side Hills; or to river channels, e.g. downstream of Mount Pearl on the Waterford River and

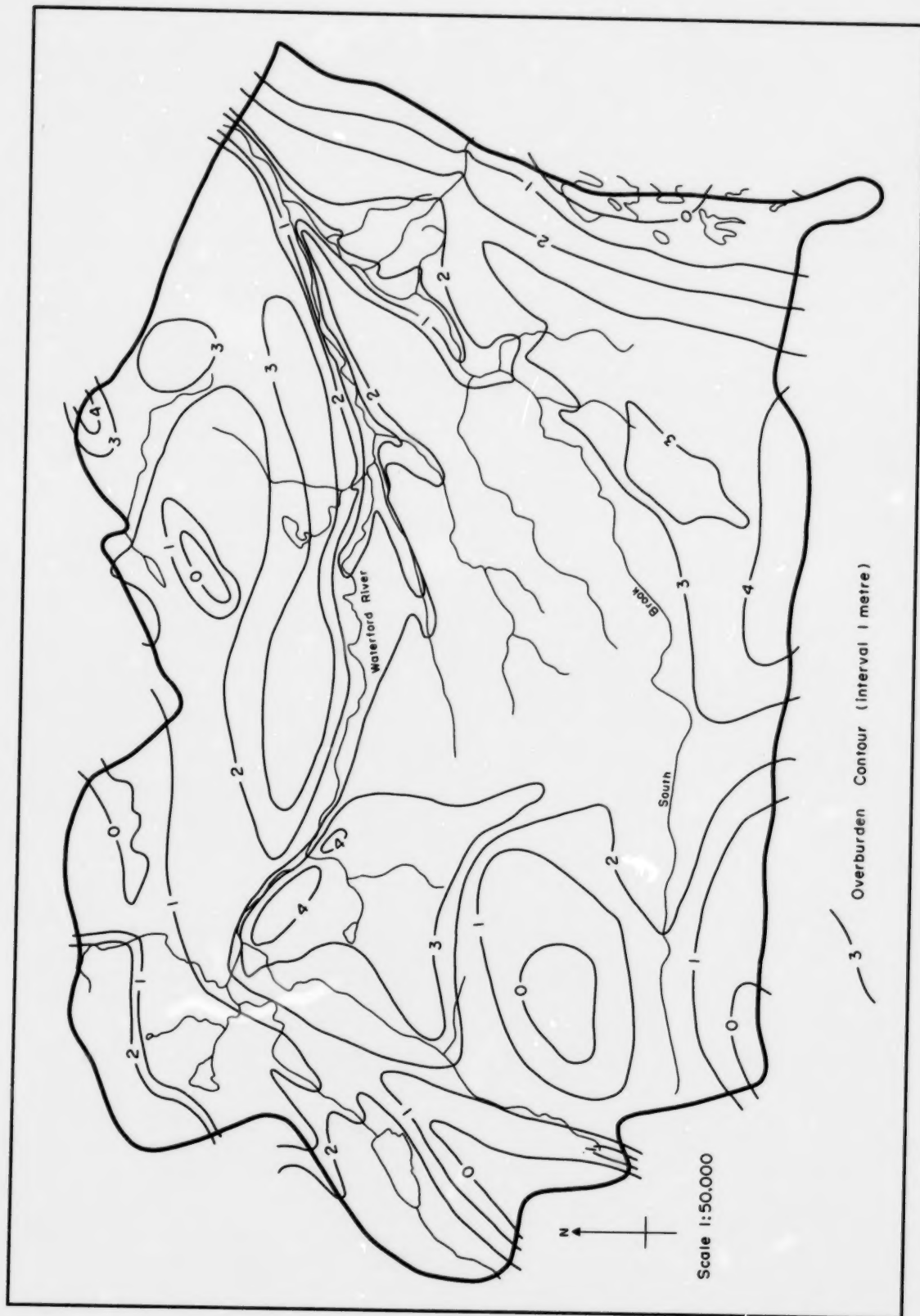


Figure 7: Summary of overburden thicknesses within the Waterford River basin. (See Map B in pocket for details.)

north and south of the headwaters of South Brook, and the South Side Hills; or to river channels, e.g. downstream of Mount Pearl on the Waterford River and downstream of the Harbour Arterial route on South Brook. These areas correspond to the Rc terrain unit described earlier.

2) Areas of thicker till (3-5 m) are restricted to the more gently sloping parts of the basin around Donovans Industrial Park, and in the Goulds-Kilbride area. These two areas correspond to Tv//Rc and Tv//Rc on the terrain map, the //Rc being a constant reminder of the numerous rock outcrops across the basin. The thickest recorded till depths were 4.5 m along the Waterford River to the west of Mount Pearl, 4.2 metres to the northeast of Kenmount Hill, 4.2 m in the extreme southwest of the basin, and a reported depth of over 5 m in the central-southern part

of the basin, although this was not confirmed by seismic readings. Depths exceeding these may occur in isolated pockets across the basin.

3) The rest of the basin, mainly the moderately sloping areas surrounding basin highs, is characterized by overburden depths of 0 to 3 m.

In general, therefore, overburden depths are at a minimum on hilltops, increase downslope to a maximum of around 4 m, and then decrease rapidly within the main river channels. I suggest that the channels are bedded on less than 2 m of overburden at all places, and in most places on less than 1 m.

Overburden depths generally increase downvalley, except in stream channels where the reverse is true, and in the Goulds-Kilbride area where

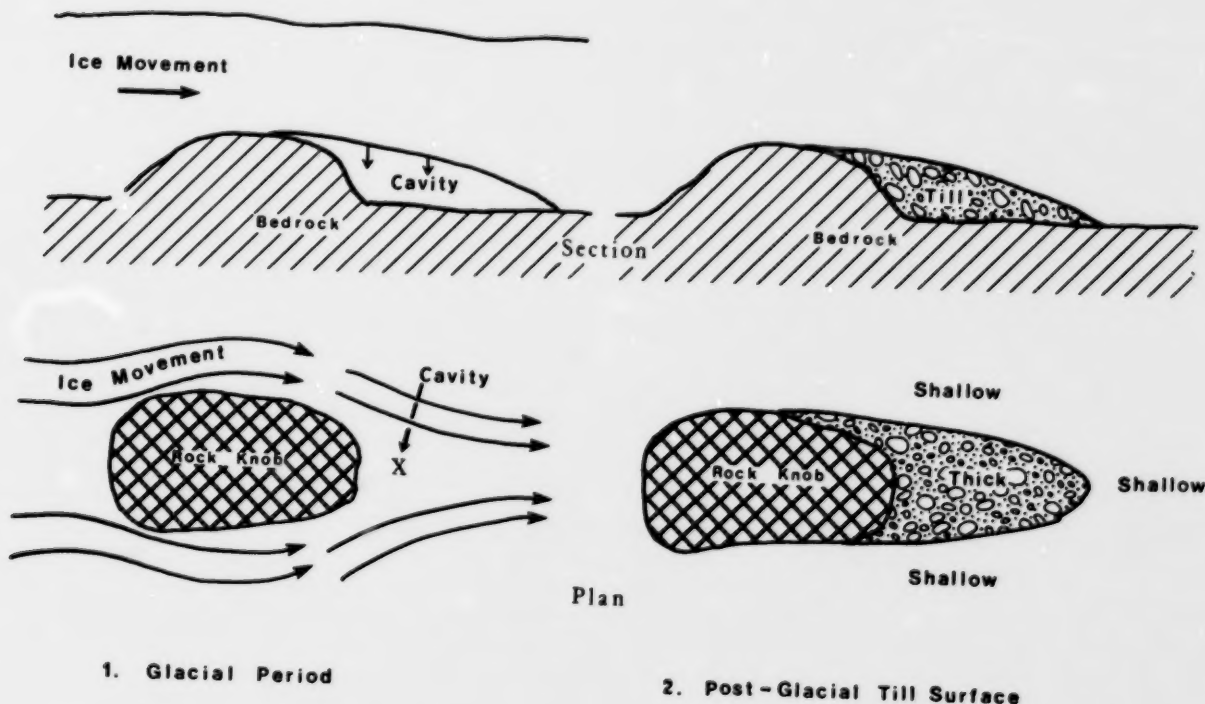


Figure 8: Development of lee-side till.

overburden thickens towards the basin headwaters in the south. The main anomaly is northeast of Kenmount Hill, where thick tills occur on hilltops. This may represent deposition within a lee-side glacial environment (Figure 8), a situation partially mirrored southwest of Mount Pearl, where up to 4.5 m of till are recorded.

The Overburden Mantle - Texture and Lithology

The surface mantle across the entire basin has a glacial origin, apart from the small areas of alluvium previously discussed. However, this general simplicity is complicated by the occurrence of three distinct units of till below the soil profile, although they rarely occur in a single stratigraphic unit.

Lodgement Till

Directly overlying the bedrock in all cases, the most widespread deposit is a very compact, light grey (Munsell Colour 2.5 Y 7/2), very poorly sorted till. The till matrix is poorly developed and exhibits a bimodal grain size distribution (Figure 9), one mode at about -1ϕ and the other at about 7ϕ . The unit is dominantly clastic and has an average silt-clay content of 10%. The clasts are all locally derived and are subrounded to subangular in shape; many are striated. The whole deposit exhibits a weak fabric. These characteristics are generally consistent with those of a subglacial lodgement till.

The character of the lodgement till results from its mode of transportation and deposition within the glacial system. Glacial loading causes overconsolidation and is often followed by a period of structural modification as pressure is released. The slight fissility recorded in the upper parts of the

subglacial unit reflects this process. The clasts are subrounded as a result of abrasion at the ice-bedrock interface, are all locally derived, and, therefore, were not transported very far. This is well illustrated at Site 128 (Map A, in pocket) in red sandstone terrain located less than 1 km down-ice from the contact with grey-green siltstones of the Conception Group. Here, despite the proximity of the contact, all subglacial clasts are angular, locally derived, coarse red sandstone. The clasts in other subglacial units are subrounded, and may reflect slightly farther transport. The clast content of the subglacial till is highly variable, appears to be unrelated to altitude or down valley distance, and may be related to local bedrock conditions.

Supraglacial Till

The second major depositional unit is exposed in the western half of the basin and on the South Side Hills. Elsewhere this facies is poorly developed, nonexistent or obscured by soil development and unrecognizable. This unit is a pale olive (5Y 6/3) to light yellowish brown (10 YR 6/4), poorly sorted, clast-supported till. Any matrix present is coarse to medium sand (Figure 10), with an average of 3.7% silt and clay. Clasts are subangular and lack striations. This description is consistent with that of a supraglacial till (Boulton, 1976), an interpretation further supported by the existence of fine sand lenses up to 20 cm long and 5 cm wide, developed by meltwater activity during deglaciation.

This supraglacial unit was apparently transported further than the underlying subglacial till. Site 128, which has a subglacial till of all local red sandstone clasts, also exhibits a supraglacial element containing pebbles of mixed origin (70%

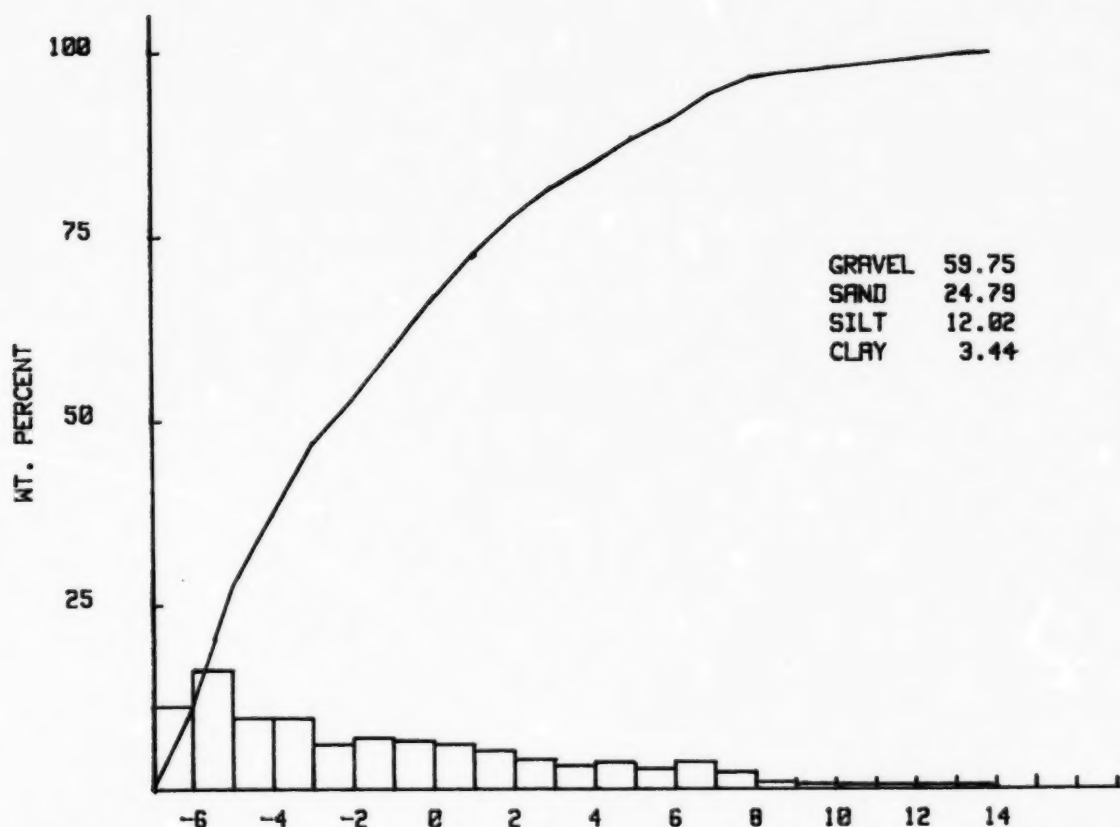


Figure 9: Grain-size distribution of typical lodgement till (Sample 54).

red sandstone, 9% quartzite of local origin, and 21% siltstones of the Conception Group).

The supraglacial unit always overlies a subglacial till and is generally better sorted, less compacted and has fewer fines than the underlying unit. The average thickness of the supraglacial unit is 50 cm, but it reaches thicknesses of 150 cm east of Donovans Industrial Park. The supraglacial tills are thickest in the west-central part of the basin and thinnest toward the basin margins. Despite being transported farther than the subglacial unit, all clasts are from sources within the map area. I suggest that transport distances may be 2 km or less.

Subglacial Melt-Out Till

Where a supraglacial till is not exposed in the basin, a third unit is often present. This deposit is a compacted, light grey (2.5 Y 7/2) to white (10 YR 8/2), poorly sorted till with a higher silt-clay content and lower clast content than the underlying lodgement till unit (Figure 11). Silt-clay content averages 18.1%. Grain size distribution is bimodal to multimodal and reflects selective transportation in the glacial system. The clasts are sub-angular to subrounded, lithologically identical to the lodgement unit, and characteristically have a thick (>0.5 mm) silt-clay coating. Some clasts are striated, but fewer than in the

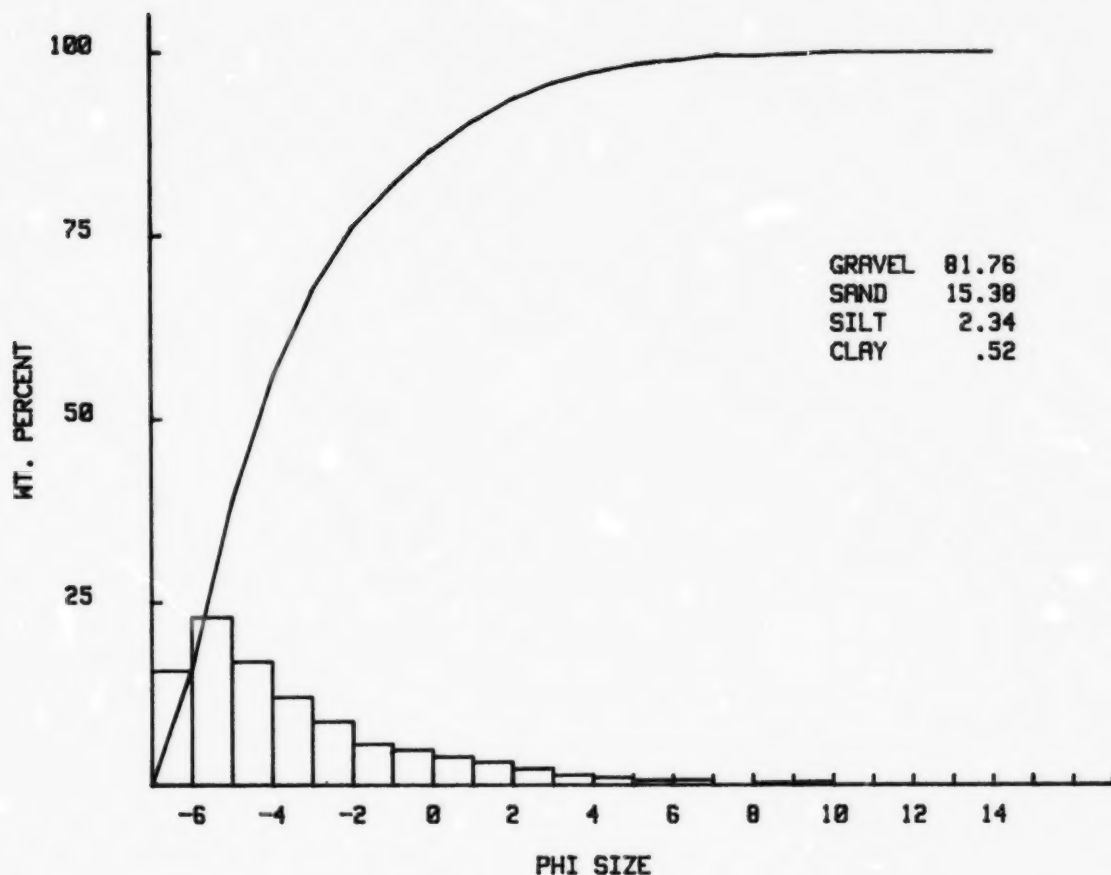


Figure 10: Grain-size distribution of typical supraglacial till (Sample 23).

underlying lodgement till. This unit has no obvious structure or fabric.

The low clast content relative to the underlying lodgement till, the thick silt-clay coating, the massive structure, and the stratigraphic position are all consistent with a description of a meltout till (Boulton, 1976; Dreimanis, 1981), probably a subglacial melt-out till due to its large silt-clay fraction.

The Overburden Texture - A Synopsis

The deposits described above are generally distinct and often readily

identifiable. However, the limited transport and the consequent immaturity of the till has produced some anomalies which appear to be a mixture of sub- and supraglacial deposits. These may reflect local areas of thinner ice where till development was restricted, e.g. Site 40, map A, located atop a small hill (183 m above sea level).

Stratigraphic boundaries are distinct between both supraglacial and subglacial, and melt-out and lodgement till units.

The deposits can be separated by comparing the textural analyses of

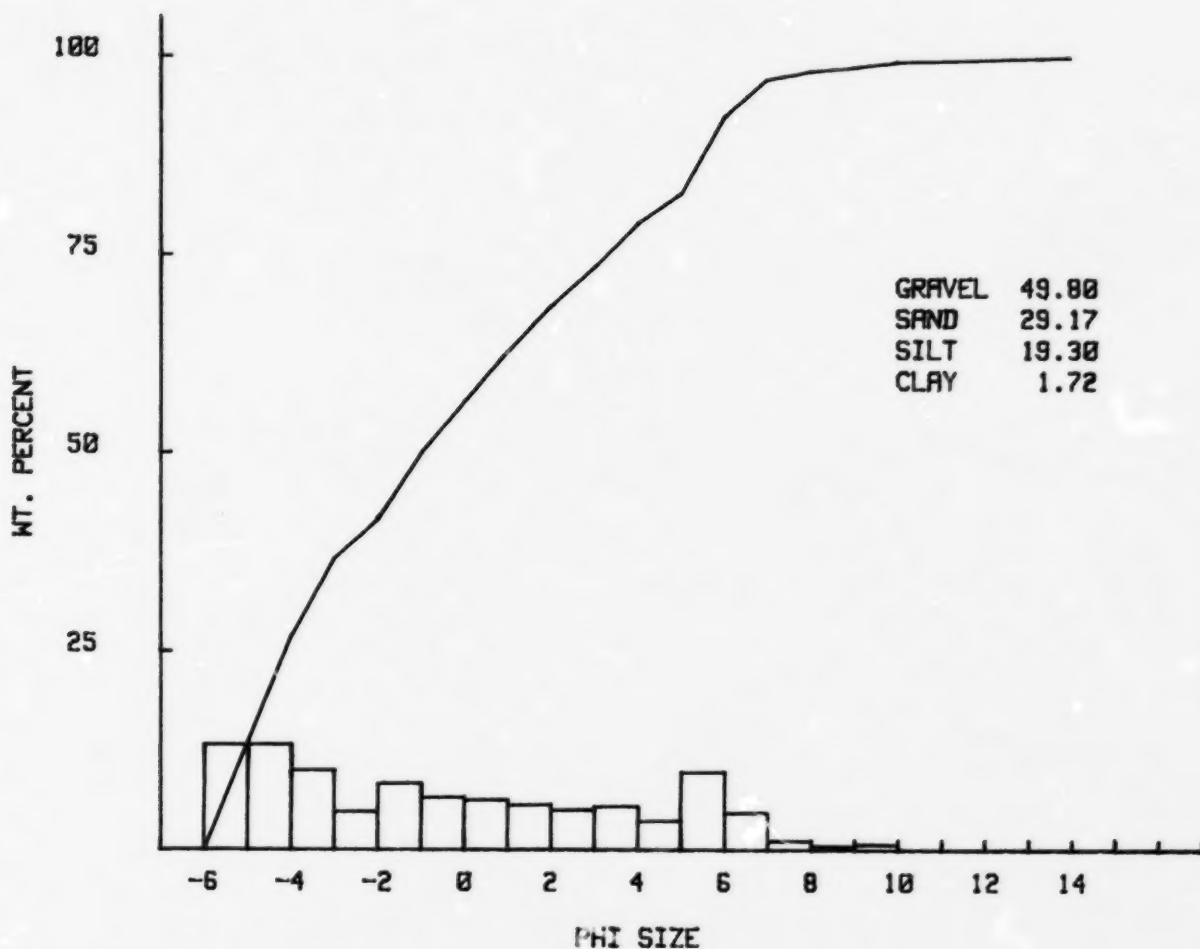


Figure 11: Grain-size distribution of typical subglacial melt-out till (Sample 68).

the finer than -3 ϕ fraction (Figure 12).

Subglacial deposits have a broad spread of values, but generally contain 15-50% gravel, 25-60% sand and 10-50% silt-clay. In all cases, there is more silt than clay; the clay averages 5.7%. This spread reflects the poor sorting of subglacial deposits. The melt-out tills do not form a discrete component of the

diagram, but fall in the finer range of the subglacial tills (silt-clay content of 25-40%).

In contrast, supraglacial deposits have a relatively small grain-size distribution. Gravel and sand percentages vary, but silt-clay content is always less than 11%. This reflects the winnowing of fines in the supraglacial environment by melt-water action.

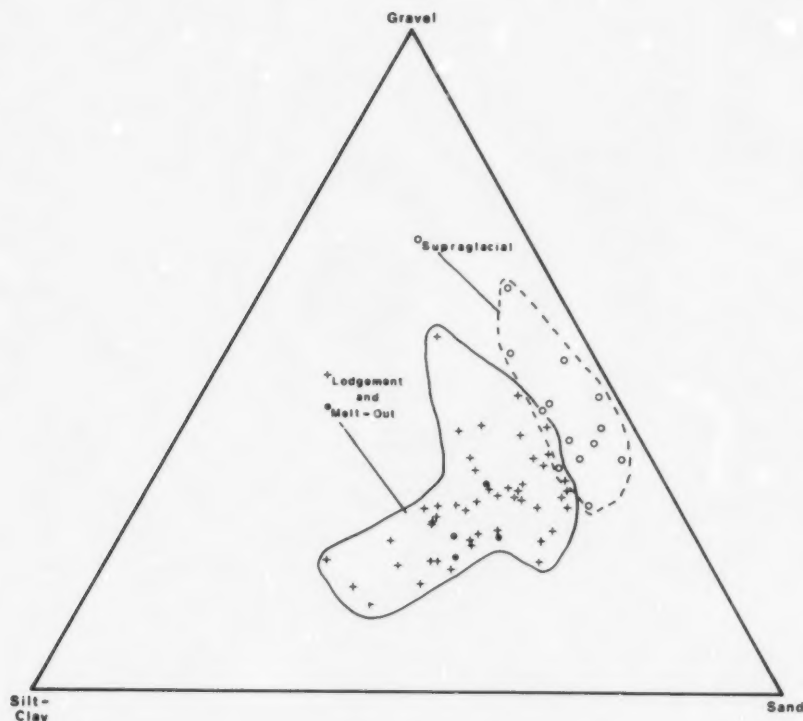


Figure 12: Triangular plot of gravel, sand and silt-clay content of finer than 8 mm fraction of all field samples.

Ice-flow Indicators

Ice movement indicators are relatively rare across the basin. Striae were noted in only three locations: southeast of Kenmount Hill (Site 2, Map A), where striations on sandstone bedrock show ice movement toward the east-northeast (azimuth 067°); southwest of Mount Pearl (Site 84), where a dominant 120° iceflow direction and a later 088° iceflow direction are preserved; and along South Brook in Bowring Park (Site 146), where an iceflow direction of 025° was recorded. From the striae, it appears that ice movement was controlled by the bedrock topography. The ice was funnelled between Kenmount Hill and the South Side Hills, and possibly exited through St. John's Harbour.

The poorly developed drumlinoid features, especially in the southeastern part of the basin, modify this hypothesis by displaying 055° ice directions along the basin margins, and a 023° direction in the Kilbride area. These readings indicate that ice movement was largely unaffected by the basin margins, at least in the south. However, the relative ages of the lineations and striae are unknown and may not be contemporaneous.

The Glacial Environment: Summary and Discussion

Three distinct glacial deposits have been described across the Waterford River basin. In all cases, a compacted lodgement till unit occurs above the bedrock; this till is over-

lain by either a subglacial melt-out or a supraglacial till. In only one location were all three till units exposed in a single stratigraphic section (Site 193).

This contrast in till units provides an insight into glacial activity throughout the basin. It is likely that a more active iceflow occurred over the low areas immediately west of the South Side Hills. This suggestion is confirmed by the presence of the poorly developed lineations on the surface till mantle. Similar lineations are not recorded in the western part of the basin. Also, the terraces developed along the South Side Hills and Kenmount Hill may be evidence of ice downwasting.

Meltwater was concentrated between the ice and the South Side Hills during deglaciation, forming a series of terraces in the till. The abundance of meltwater in this area may explain the lack of supraglacial deposits. To the west, around Donovans, meltwaters were less abundant and deglaciation was a downwasting process during which the supraglacial mantle was emplaced upon the underlying units. Associated meltwaters may have been responsible for the terrace around the Clearview Drive-In area, although this hypothesis is unconfirmed. Ice in this area was probably stagnant while ice to the east was still active.

In general, the evidence within the Waterford River basin conforms with the accepted ideas of the glacial history of this part of the Avalon Peninsula, that is, a thin ice cover over the St. John's Peninsula which followed the pre-existing bedrock topography in a roughly southwest-northeast direction. The tills are poorly developed and variable in thickness and were only transported short distances. However, variation in flow regime and deglaciation

patterns did occur across the basin. A more active flow to the east produced the lineations, followed by meltwater concentration, along the South Side Hills. To the west, more stagnant ice conditions prevailed and a full suite of till was deposited. Whether active ice flow in the east and more stagnant conditions to the west were contemporaneous cannot be stated with certainty.

IMPLICATIONS OF THE SURFICIAL GEOLOGY TO THE HYDROLOGY OF THE WATERFORD RIVER BASIN

This report outlines in detail the surficial components of the Waterford River basin. The overburden thicknesses and characteristics have been described and these data may be used as an aid in the analysis of collected hydrological data. Glaciation has modified the preglacial topography, mainly by filling bedrock depressions with tills, and erosion of the postglacial topography is an ongoing process.

There are several implications to the hydrology of the basin.

1) The major stream channels have actively incised the overburden mantle. I suggest that stream channels are generally flowing over less than 2 m of overburden, while in their lower reaches, flow is over or through bedrock.

2) Till units throughout the basin consist of a very compact lodgement till with an 11% average silt-clay content. This is, in the west especially, overlain by a less compacted, coarser supraglacial deposit often only 50 cm thick. Percolation into and through the upper layer, with its coarse texture and low silt-clay content (average 4%), would be relatively fast compared with percolation through the lower lodgement till unit. Pore spaces in the lower till are small due to the

higher silt-clay content and overconsolidation and, therefore, water movement through this till is seriously restricted. Similarly, discharge is also slow, but probably continuous even through long periods of drought. The lodgement till contains no fractures through which rapid discharge may be facilitated. During precipitation, the upper supraglacial unit is rapidly saturated, developing a perched water table, often with surface ponding of water. Where the supraglacial unit is absent, ponding of water will also occur in topographic lows underlain by the subglacial till.

3) Partially as a result of the compaction of the subglacial till, many surface ponds developed upon deglaciation. Since then, these ponds have been gradually filled by vegetation through a succession process, to become the large number of isolated bogs of today.

4) Due to the thinness of the overburden mantle, the bedrock exerts a critical control over the movement of water throughout the whole basin. Therefore, the hydrological response of the drainage basin to precipitation events is rapid.

5) Urban development now and with further expansion will affect the movement of water through the basin. Removing the vegetation accelerates the surface flow into the drainage system, while urban construction damages the critical supraglacial layer, thereby reducing the overall storage capacity of the groundwater environment. Runoff and flooding potential increase, factors which are compounded in the lower Waterford River basin by its narrow, incised nature. Increased flooding is more likely to occur in this and other areas of the basin in the future. The construction of the Sobeys Square Mall on Topsail Road is a case in point. Before development, water

movement was downslope through the overburden mantle into the Waterford River. However, storm sewer construction bypassed the overburden and directed water into a small tributary. Incision of its channel increased rapidly, and sediment content of the stream also increased.

The rapid increase of water into the Waterford River system as a result of urban drainage will increase incision of its channel into the remaining overburden mantle and also increase its sediment content. Similarly, the geochemistry of the river will change since the filtering effect of the till is removed.

In general, the thinness of the overburden and the compaction of the subglacial unit have major influences on groundwater movement throughout the Waterford River basin.

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Appendix A

Consulting and Related Reports from which Overburden Thickness Data was obtained

Data Points

- 200-250 St. John's Regional Water System (Nolan, White and Associates, Project #4550)
- 251-255 Soil Investigation, CMHC Project, Mount Pearl Phase 1-A, Mount Pearl, Newfoundland. April 1973. (Geotechnical Associates Ltd. for Newfoundland Design Associates Ltd. Project #G233/113).
- 256-269 Geologic Evaluation of Soil Conditions and Topographic Forms. Proposed Industrial Complex - Satellite City. Mount Pearl, Newfoundland. May 1970. (Racey, MacCallum and Bluteau Ltd. for Newfoundland Design Associates Ltd. Project #53244/N 454).
- 270-288 Mount Pearl Newfoundland Project. January 1969. (Murray V. Jones and Associates for Newfoundland Design Associates).
- 289-346 Bedrock and Surficial Geology of the St. John's Area, 1973. (Rhodenizer, C. Unpub. B.Sc. thesis, Geology, M.U.N.).
- 347-348 Subsoil Investigation - Proposed Provincial Agricultural Building. Brookfield Road, St. John's, Newfoundland, October 1979. (Geotechnical Associates Ltd. Project #G222/742).
- 349-350 St. John's Harbour Arterial - Preliminary Report Nov. 1970. (F.J. Nolan and Associates Ltd. for Fenco Newfoundland Ltd. Project #0125-1).
- 351 Subsoil Investigation, City Refuse Dump Area, Mount Pearl, Newfoundland. October 1973. (Geotechnical Associates Ltd. for Newfoundland Design Associates Ltd. Project #G233/191).
- 352-353 Waterford River Basin Study - Monitoring Well Installation Report Site A and Site C respectively. (Water Resources Division, Department of Environment, St. John's, Newfoundland 1981).
- 354-363 Data provided by Environmental Geology Section, Department of Mines and Energy, St. John's, Newfoundland.

Appendix B

Grain-Size Data
of finer than 8 mm fraction

<u>Site No.</u>	<u>Sample No.</u>	<u>Depth(cm)</u>	<u>Origin*</u>	<u>Gravel%</u>	<u>Sand%</u>	<u>Silt%</u>	<u>Clay%</u>
3a	00	90	Ld	13.5	37.5	40.3	8.7
	01	50	Mo	24.5	49.9	24.0	1.7
14	02	100	Ld	20.3	56.9	16.0	6.8
16	03	60	Ld	30.2	46.3	21.5	2.1
19	04	100	Sp	45.4	52.3	2.3	0.0
	05	125	Ld	32.0	47.1	18.3	2.7
32	06	75	Sp	34.1	52.5	13.4	0.0
	07	100	Ld	24.9	56.9	18.2	0.0
33	08	95	Ld	30.4	49.0	19.4	1.3
	09	75	Sp	38.0	54.7	7.3	0.0
35	10	80	Sp	29.2	59.3	11.5	0.0
	11	200	Ld	28.4	43.0	23.9	4.8
40	12	100	Sp	39.2	52.3	8.5	0.0
42	13	250	Ld	34.4	52.4	12.1	1.2
47	14	70	Sp	31.0	54.7	12.4	1.9
	15	150	Ld	25.3	48.8	21.7	4.2
57	16	100	Ld	35.8	48.0	15.9	0.3
67	17	80	Ld	27.2	39.9	31.7	1.3
70	18	80	Ld	28.3	53.9	13.3	4.5
	19	50	Sp	51.0	45.2	3.0	0.8
80	20	60	Sp	52.3	36.7	9.1	1.9
87	21	100	Ld	23.2	35.5	28.6	12.8
88	22	150	Ld	29.4	41.3	20.0	9.3
89	23	50	Sp	43.9	47.3	7.2	1.6
94	24	60	Ld	19.9	43.5	24.5	12.1
97	25	80	Ld	40.8	38.6	19.3	1.3
98	26	100	Ld	22.9	46.3	24.3	6.6

Appendix B (continued)

<u>Site No.</u>	<u>Sample No.</u>	<u>Depth(cm)</u>	<u>Origin*</u>	<u>Gravel%</u>	<u>Sand%</u>	<u>Silt%</u>	<u>Clay%</u>
101	27	200	Ld	54.1	27.0	14.6	4.3
103	28	80	Mo	23.3	44.1	26.5	6.2
	29	250	Ld	39.3	45.4	13.9	1.4
106	30	110	Ld	35.6	54.6	8.3	1.5
109	31	150	Ld	26.2	40.4	21.9	11.5
111	32	70	Ld	34.4	40.6	21.7	3.4
116	33	100	Ld	16.4	34.2	37.3	12.2
118	34	80	Ld	40.0	54.8	11.7	3.5
	35	50	Mo	33.0	53.3	9.9	3.9
122	36	80	Ld	32.2	47.7	14.5	5.6
124	36a	200	Ld	39.6	36.5	16.4	7.5
128	37	150	Ld	17.2	42.6	34.1	6.1
	38	30	Sp	62.3	32.0	4.3	1.5
133	39	120	Ld	25.9	40.4	26.4	7.4
139a	42	100	Sp	35.5	52.6	7.8	4.2
	47	200	Ld	18.4	39.3	30.0	12.2
140	41	150	Ld	28.2	37.9	25.6	8.4
141	43	200	Ld	33.2	54.4	8.9	3.5
142	44	200	Ld	36.3	40.2	20.1	3.3
144	45	120	Ld	33.2	48.8	14.9	3.1
149	46	120	Ld	18.5	46.2	27.4	7.9
152	48	150	Ld	27.8	57.1	12.0	3.2
154	49	150	Ld	44.5	42.0	9.9	3.7
159	50	60	Ld	22.7	56.3	16.3	4.7
161	51	150	Ld	40.9	47.2	8.6	3.3
166	52	150	Ld	35.1	49.7	12.3	2.9

Appendix B (continued)

<u>Site No.</u>	<u>Sample No.</u>	<u>Depth(cm)</u>	<u>Origin*</u>	<u>Gravel%</u>	<u>Sand%</u>	<u>Silt%</u>	<u>Clay%</u>
169	53	100	Ld	28.9	38.9	27.3	4.9
171	54	200	Ld	24.4	46.6	22.6	6.5
175	55	80	Ld	30.5	45.1	18.8	5.6
177	57	200	Ld	20.0	43.2	30.0	6.9
	58	100	Sp	37.2	53.8	6.2	2.8
179	59	170	Ld	19.7	29.2	35.8	15.4
181	61	100	Ld	27.5	39.3	20.8	12.5
185	62	120	Ld	21.7	41.9	26.8	9.7
	63	70	Sp	36.1	60.1	2.4	1.5
188	64	200	Ld	36.7	49.6	9.9	3.9
	65	100	Sp	40.5	55.3	2.6	1.6
193	66	100	Sp	43.4	45.5	8.4	2.7
	67	250	Ld	29.1	50.4	15.3	5.3
	68	160	Mo	20.7	46.1	30.5	2.7

* Sp = Supraglacial Till
 Mo = Subglacial Melt-Out Till
 Ld = Lodgement Till

Note: All raw data is available upon request

Appendix B (continued)

Conversion Table

ϕ	mm
-6	64
-5	32
-4	16
-3	8
-2	4
-1	2
0	1
1	0.5
2	0.25
3	0.125
4	0.0625
5	0.0313
6	0.0156
7	0.0078
8	0.0039
9	0.0020
10	0.0010
11	0.0005
12	0.00024
13	0.00012
14	0.00006

Grain-Size Parameters

Gravel	Coarser than -1ϕ
Sand	-1ϕ to 4ϕ
Silt	4ϕ to 8ϕ
Clay	Finer than 8ϕ

**MAPS
NOT
FILMED**

**CARTES
OMISES**